Anti-proton Acceleration in the MI using 2.5 MHz (h=28) and 53 MHz (h=588) RF Systems

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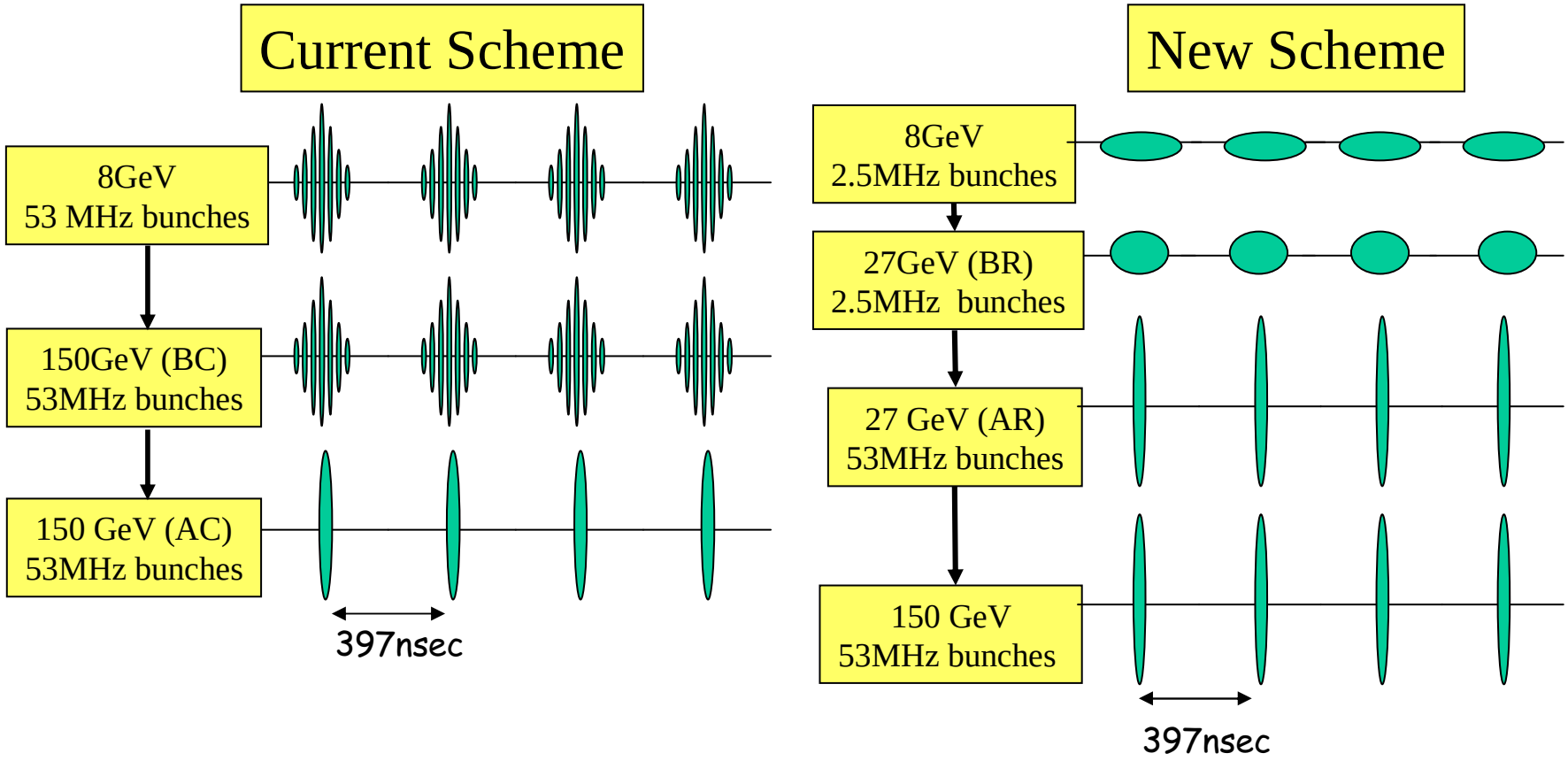
- Dave Wildman
- Many Individuals in the MI/RF Group
- Operation group

Outline

- Scheme and Project Goal
- Simulations
- Beam Studies
- Future Plans

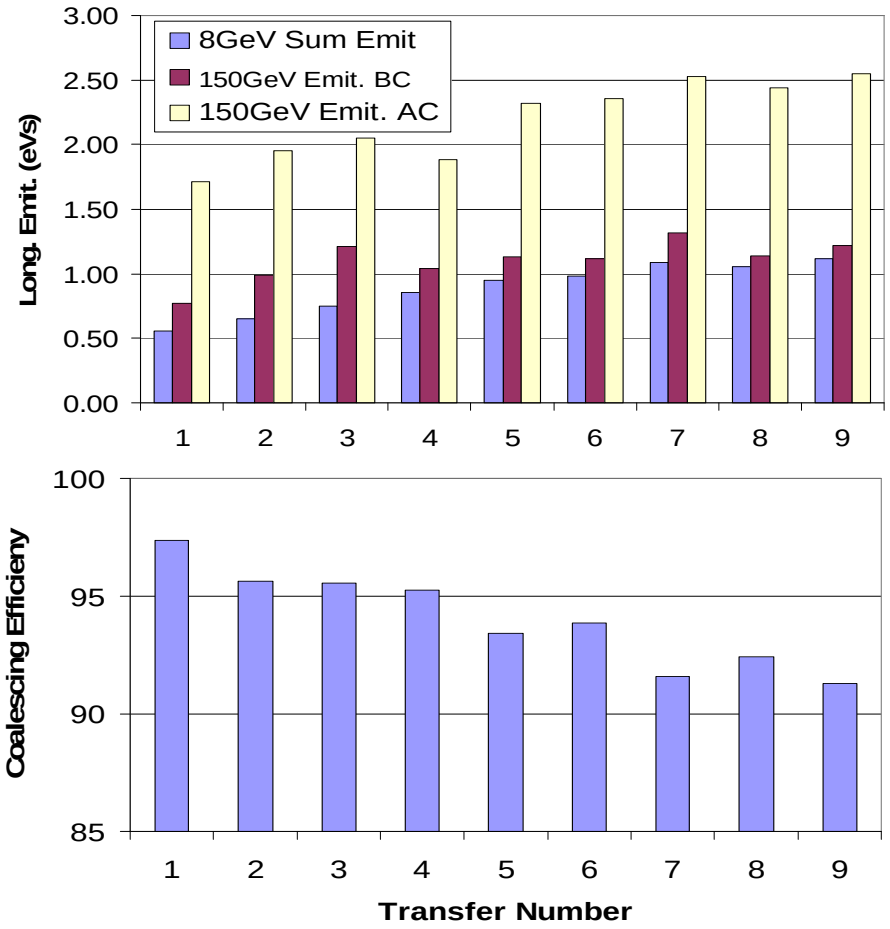
Pbar Acceleration Schemes

(Current vs New)



Why New Scheme?

The current pbar Acceleration scheme gives



- Run II upgrade plan calls for pbar ε_l<2.5 eVs/bunch for the Tevatron at collisions.
- Pbars from Accumulator at 8 GeV ε_l~0.5-1.2 eVs. With current scheme ε_l (150 GeV)~1.7- 2.5 eVs.
- Pbars from Recycler at 8 GeV ε_l~1.5-2 eVs

  ⇒ It is important to minimize emittance dilution in the MI

The 2.5MHz Acceleration Scheme

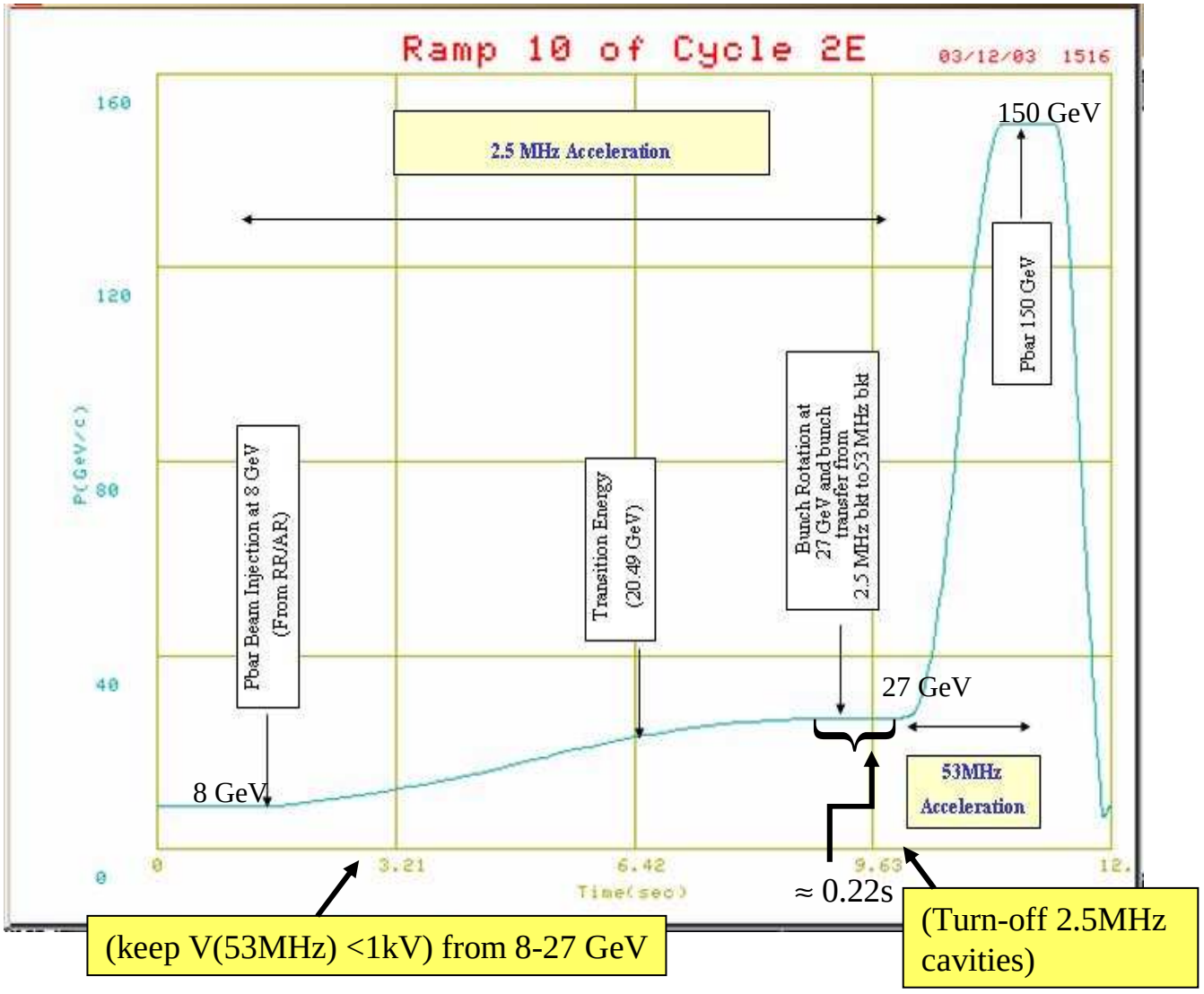
⇒ 2.5MHz pbar beam from RR/AR →MI @ 8GeV

⇒ Accelerate to 27 GeV using 2.5MHz RF system

⇒ Harmonic transfer from h=28 →h=588 @ 27 GeV

⇒ Complete acceleration from 27 to 150 GeV using 53MHz RF system

("RR Technical Design Report" Fermlab-TM-1991, Nov. 1996)



Technical Review of the Project

- A technical review was held in October 2003 to evaluate the project status, better understand the project scope and prioritize accordingly.

- Review info. and a detailed document are available on web

http://wwwbd.fnal.gov/run2upgrade/reviews/2.5MHz_acc_MI_Oct03.html

http://www-bdnew.fnal.gov/doereview04/index.htm

- The committee strongly recommended to proceed with the project.

Project Goals

- Initial Parameters:
  - Four 2.5MHz pbar bunches separated by 397ns at injection for every MI acceleration cycle.
  - Longitudinal emittance ≈ **0.8 – 2.2 eVs**
  - Bunch intensities ≈**50-170E9** pbars/bunch

- At 150GeV
  - 53MHz bunch separation of 397 ns,
  - Longitudinal emittance growth <50% with no beam loss.
  - Time gap between consecutive pbar transfers to Tevatron ~60 sec with a total of nine transfers

Near-term goal : Demonstrate the scheme for 60E9 pbars/bunch for ε_l = 1-1.5 eVs

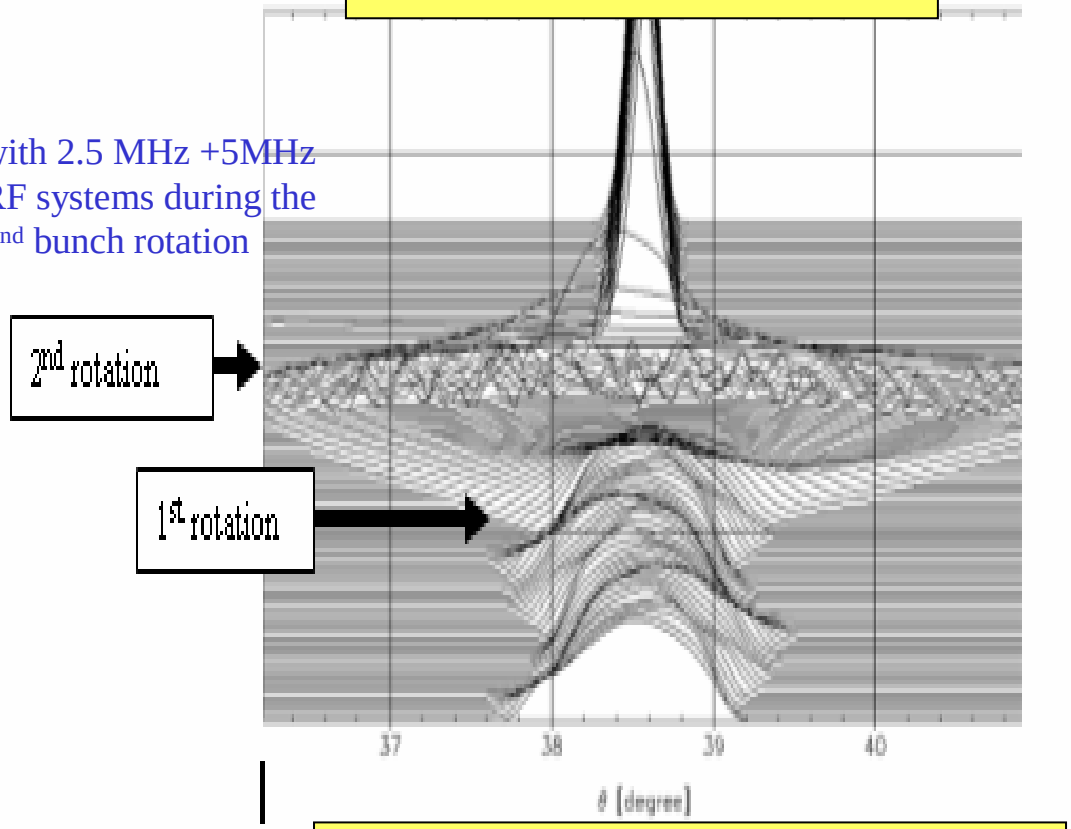
Long-term goal: Demonstrate the scheme for 170E9 pbars/bunch with ε_l = 0.8-2.2 eVs (for Recycler era)

ESME Simulation

170E9@1.5eVs

Mountain-range during 27GeV bunch rotation

with 2.5 MHz +5MHz RF systems during the 2nd bunch rotation



For acceleration from 8-150 GeV
- Up to 35% emittance dilution
- ~100% transmission efficiency

- Standard Transition phase jump
- Including feed forward (FF) and feed back (FB) BLC for 2.5MHz and 53MHz RF systems, space charge force
- Simulations also carried out for bunch intensity ≤170E9 pbars, ε_l = 0.8-2.8 eVs

HLRF Specifications

(For highest Intensity bunches)

- Beam Loading Compensation
  - 2.5MHz Feed-back (FB) factor of 5
  - 2.5MHz Feed-forward (FF) factor of 10
  - 53MHz Feed-back factor of 5
  - 53MHz Feed-forward factor of 10

} HLRF group has implemented BLC but needs to be optimized

- 53MHz rf voltage <400V during the 2.5MHz acceleration from 8-27 GeV and bunch rotation

Beam Studies

Beam properties and RF parameters

- **Proton Beam**
  - Four 2.5MHz bunches at 8 GeV
  - 20E9-80E9 protons/bunch
  - Long. emit. : 0.8eVs -2.2eVs

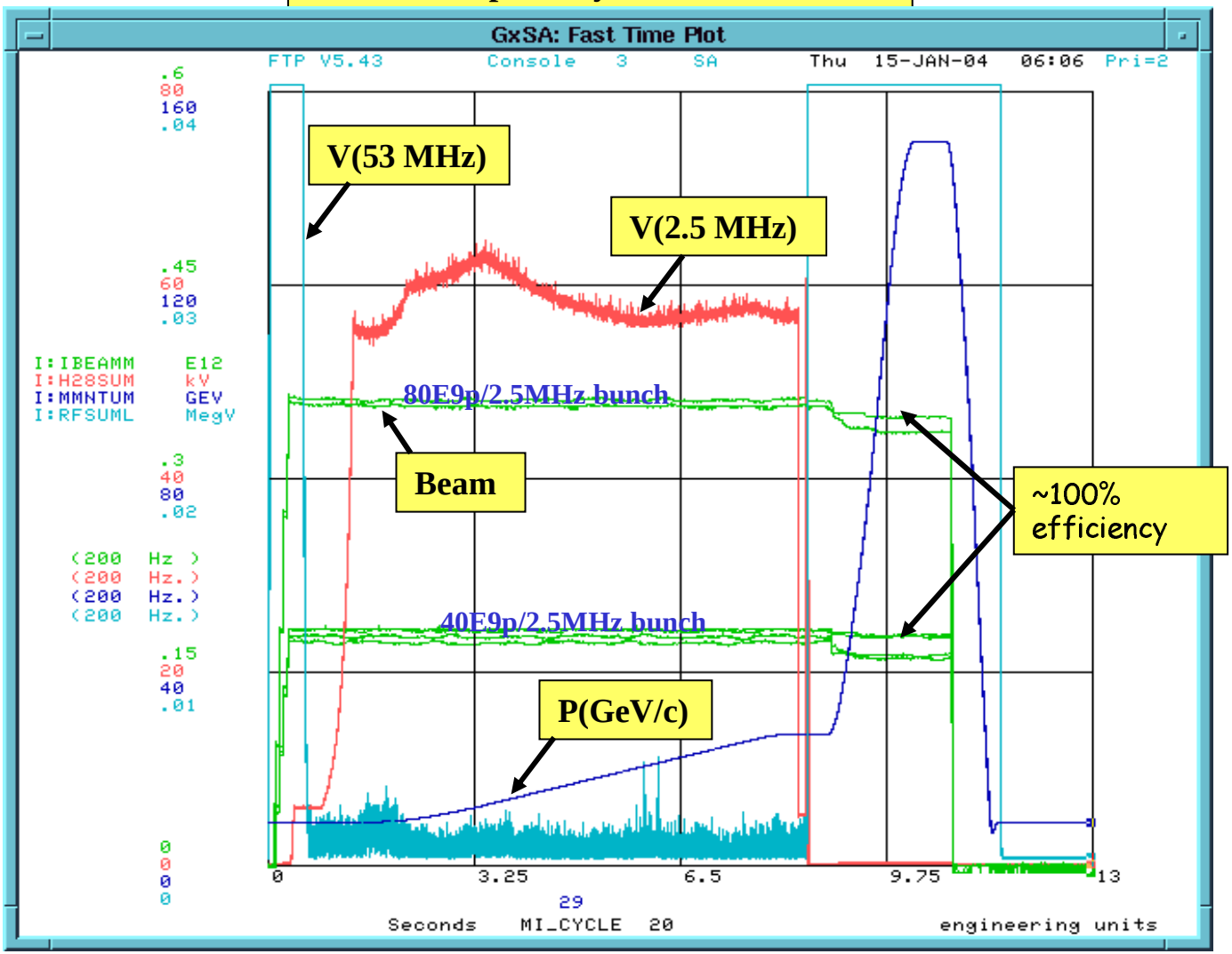
- **RF:**
  - Partially commissioned 2.5MHz and 53MHz FB & FF BLC
  - With 2.5MHz and 53MHz radial-position loop and phase control

Many of the HLRF and LLRF requirements for this scheme are already covered in the Run II and other upgrade projects like, "**coalescing scheme for protons and anti-protons at 150 GeV**", "**slip-stacking**", and "**Beam transfer to the Recycler at 8 GeV**"

8-150 GeV Acceleration

⇒ 53MHz RF system paraphased down to ~2kV, during 8-27 GeV

Studies with partially commissioned BLC



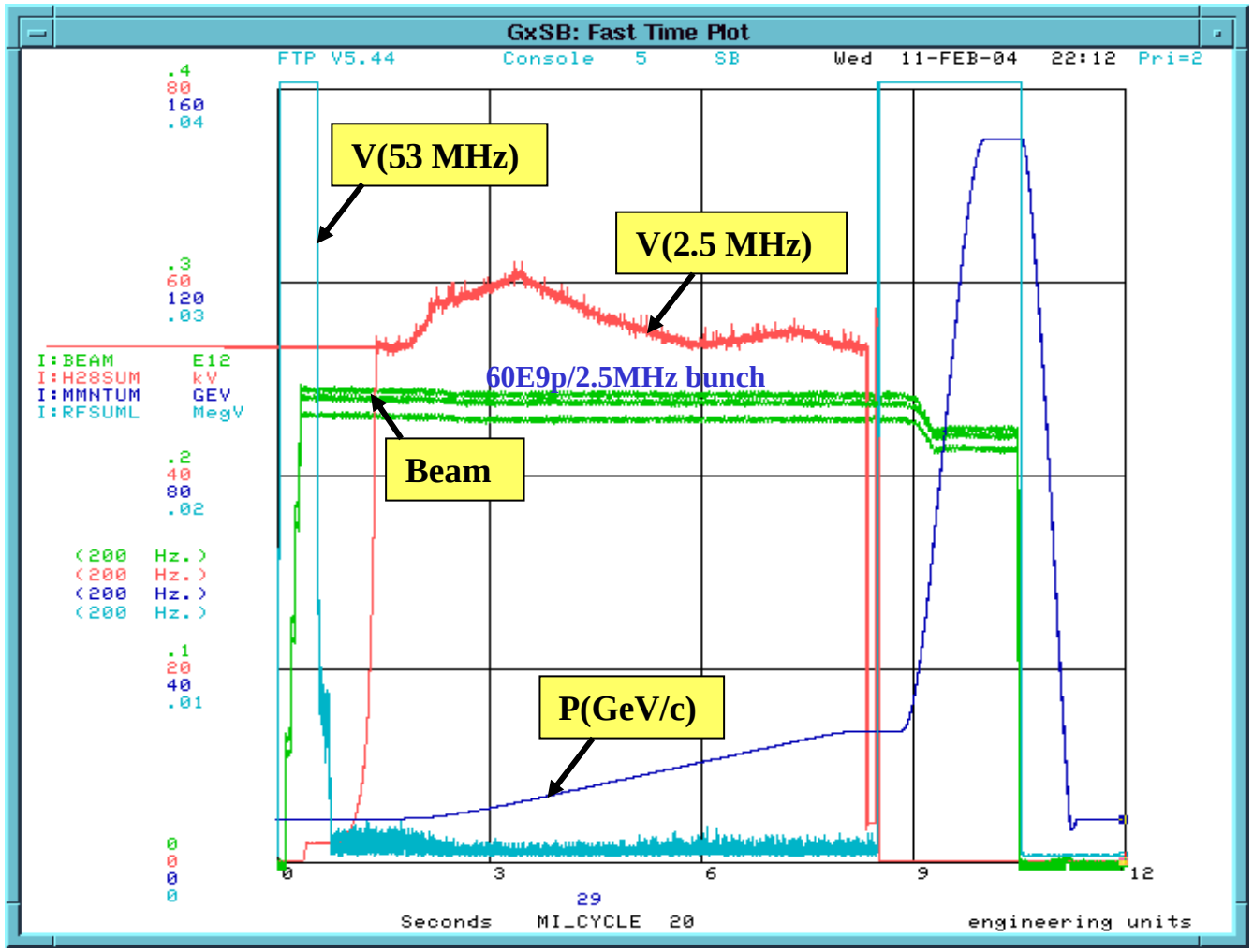
We used
- 2.5MHz radial and phase control for acceleration from 8-27 GeV
- 53MHz radial and phase control for rest of acceleration

Max. beam loss ~10% possibly due to switching RPOS at 27 GeV

8-150 GeV Acceleration

⇒ 53MHz RF system station OFF from 8-27 GeV

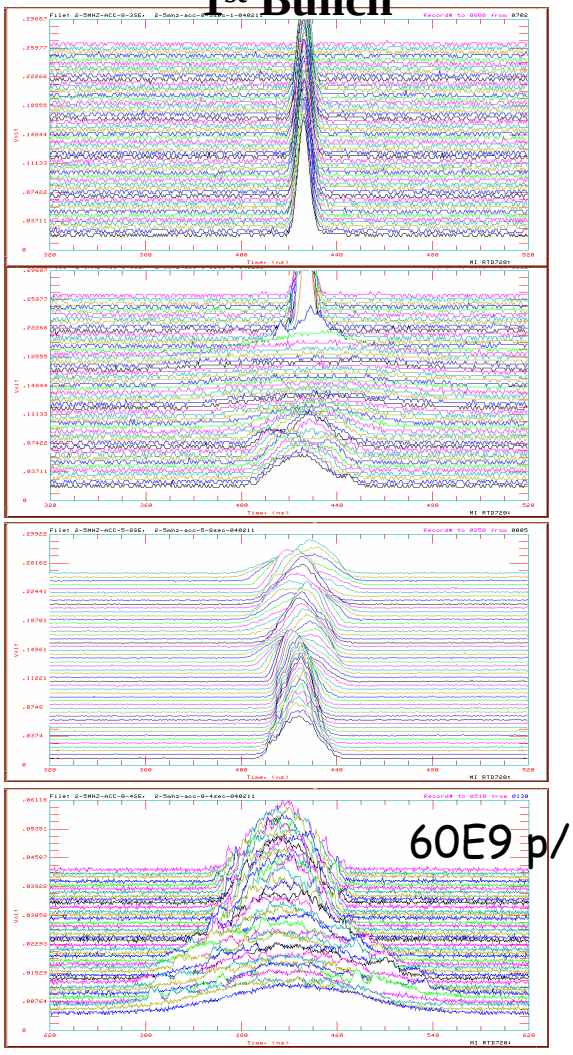
Studies with partially commissioned BLC



Max. beam loss ~10% possibly due to

- switching RPOS at 27 GeV
- 53 MHz RF turn-on transient

WCM data and Emittance Measurements



	<ε_l>	<Efficiency>
150GeV	2.1 eVs	86%
27GeV Harmonic Transfer	2.0 eVs	87%
	1.9 eVs	100%
20.5GeV Transition Crossing		
8 GeV @ accel.	2.1 eVs	100%
8 GeV @ Inj.	2.1 eVs	100%

Future Plans

With Protons

- Improve the 8-150GeV transmission efficiency with fully commissioned BLC
  - Transition crossing
  - 27 GeV bunch rotation (with 5MHz rf system added) and 53MHz capture,
  - Switching the radial position and phase controls from 2.5MHz system to 53MHz system.
- Emittance measurements using SBD
- Acceleration with 170E9protons/bunch

With Pbars

- Use this acceleration scheme with pbars from the Recycler to Tevatron

Issues

Reliability

- Transition crossing:
  - There are some intensity dependent effects which arise from beam-loading of 2.5MHz and 53MHz rf systems.

    Preliminary results with BLC is very encouraging.

- How well do we keep Vrf(53MHz) low reliably during 8-27 GeV acceleration and harmonic transfer?
  - A special **vector control box** is being developed by RF group to para-phase (Ralph is going to talk about this in detail) and/or combination of RF station "OFF"

Summary

- We have investigated a a new pbar acceleration scheme in the MI for collider operation.
- This scheme is expected to give $\Delta\varepsilon_l$ **<50%** from **8-150GeV** with no beam loss.
- Expect that the collider program will be benefited particularly during RR era with this scheme in place
- Beam dynamics simulations, for ε_l=0.8-2.8eVs, intensities = 60-170E9pbars /bunch predict that <35% emittance growth with no beam loss from 8-150 GeV.
- Have carried out beam studies with protons using partially commissioned BLC for beam intensity = 20-80E9p/bunch and ε_l=0.8-2eVs.
  - Have seen transmission efficiency ~100% from 8-150 GeV acceleration for < 80E9 p/bunch
  - Within the measuremental errors we do not see emittance growth.

The Results from beam studies are very promising

We need MRF(for better phase and amplitude control) asap to make this scheme operational